Operational Emergency Response Modeling Systems for Use with Major Releases of Airborne Hazards

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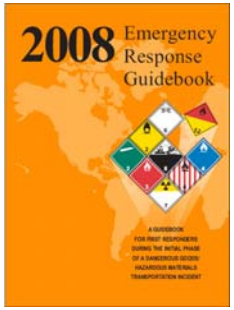
Tools for Estimating Hazard Areas

1. **Guidebooks and guidelines**



2. **Computer models of atmospheric transport, dispersion and deposition**

3. **Measurements of air concentration and ground contamination**

The Emergency Response Guidebook Table is Based on a Series of Default Model Runs

Pre-determined hazard distances and protective action recommendations are based on type of accident and hazardous material

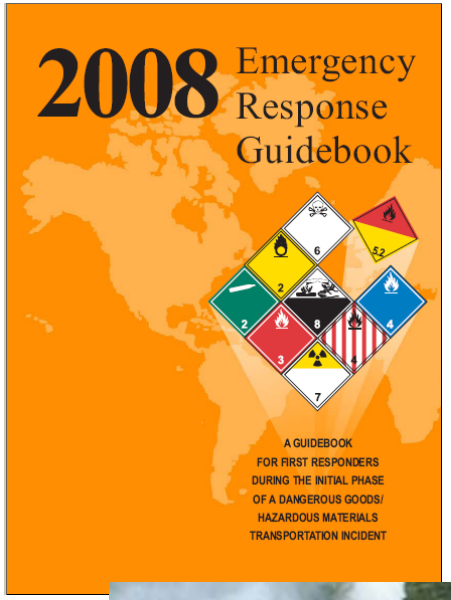


TABLE 1 - INITIAL ISOLATION AND PROTECTIVE ACTION DISTANCES

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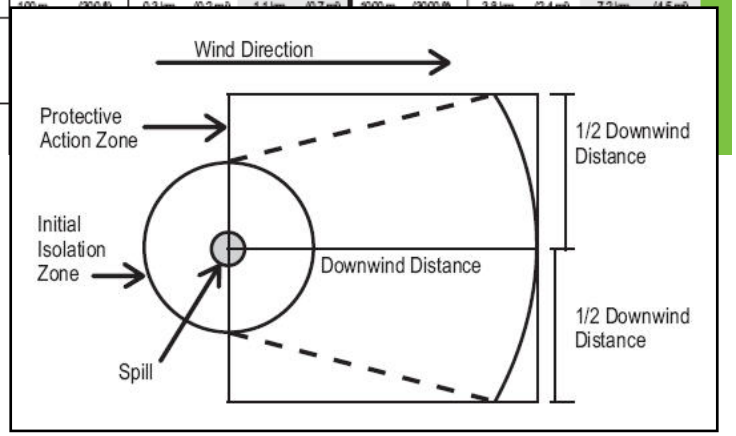
ID No.	NAME OF MATERIAL	SMALL SPILLS (From a small package or small leak from a large package) First ISOLATE in all Directions Meters	(Feet)	Then PROTECT persons Downwind during- DAY Kilometers (Miles)	NIGHT Kilometers (Miles)	LARGE SPILLS (From a large package or from many small packages) First ISOLATE in all Directions Meters	(Feet)	Then PROTECT persons Downwind during- DAY Kilometers (Miles)	NIGHT Kilometers (Miles)
1005	Ammonia, anhydrous	30 m	(100 ft)	0.1 km	(0.1 mi)	0.2 km	(0.1 mi)	150 m	(500 ft)	0.8 km	(0.5 mi)	2.3 km	(1.4 mi)
1005	Anhydrous ammonia												
1008	Boron trifluoride	30 m	(100 ft)	0.1 km	(0.1 mi)	0.6 km	(0.4 mi)	300 m	(1000 ft)	1.9 km	(1.2 mi)	4.8 km	(3.0 mi)
1008	Boron trifluoride, compressed												
1016	Carbon monoxide	30 m	(100 ft)	0.1 km	(0.1 mi)	0.1 km	(0.1 mi)	150 m	(500 ft)	0.7 km	(0.5 mi)	2.7 km	(1.7 mi)
1016	Carbon monoxide, compressed												
1017	Chlorine	60 m	(200 ft)	0.4 km	(0.3 mi)	1.6 km	(1.0 mi)	600 m	(2000 ft)	3.5 km	(2.2 mi)	8.0 km	(5.0 mi)
1023	Coal gas	30 m	(100 ft)	0.1 km	(0.1 mi)	0.1 km	(0.1 mi)	60 m	(200 ft)	0.3 km	(0.2 mi)	0.4 km	(0.3 mi)
1023	Coal gas, compressed												
1026	Cyanogen	30 m	(100 ft)	0.2 km	(0.1 mi)	0.9 km	(0.5 mi)	150 m	(500 ft)	1.0 km	(0.7 mi)	3.5 km	(2.2 mi)
1026	Cyanogen gas												
1040	Ethylene oxide	30 m	(100 ft)	0.1 km	(0.1 mi)	0.2 km	(0.1 mi)	150 m	(500 ft)	0.8 km	(0.5 mi)	2.5 km	(1.6 mi)
1040	Ethylene oxide with Nitrogen												
1045	Fluorine	30 m	(100 ft)	0.1 km	(0.1 mi)	0.3 km	(0.2 mi)	150 m	(500 ft)	0.8 km	(0.5 mi)	3.1 km	(1.9 mi)
1045	Fluorine, compressed												
1048	Hydrogen bromide, anhydrous	30 m	(100 ft)	0.1 km	(0.1 mi)	0.4 km	(0.3 mi)	300 m	(1000 ft)	1.5 km	(1.0 mi)	4.5 km	(2.8 mi)
1050	Hydrogen chloride, anhydrous	30 m	(100 ft)	0.1 km	(0.1 mi)	0.4 km	(0.2 mi)	60 m	(200 ft)	0.3 km	(0.2 mi)	1.4 km	(0.9 mi)
1051	AC (when used as a weapon)												
1051	Hydrocyanic acid, aqueous solutions, with more than 20% Hydrogen cyanide												
1051	Hydrogen cyanide, anhydrous, stabilized												
1051	Hydrogen cyanide, stabilized												
1052	Hydrogen fluoride, anhydrous												



Used for transportation accidents with known material and quantity at risk

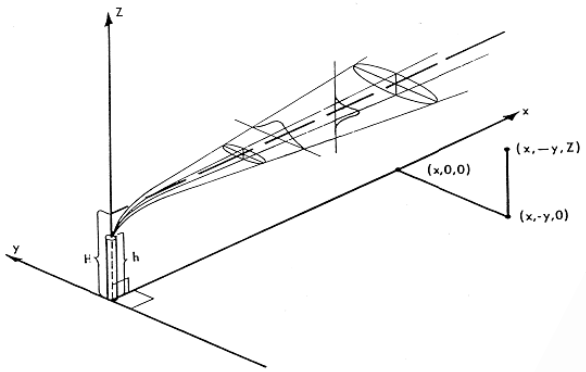
Dispersion Models are Useful for Estimating Impacts from Major or Complex Airborne Releases

Major incidents include:

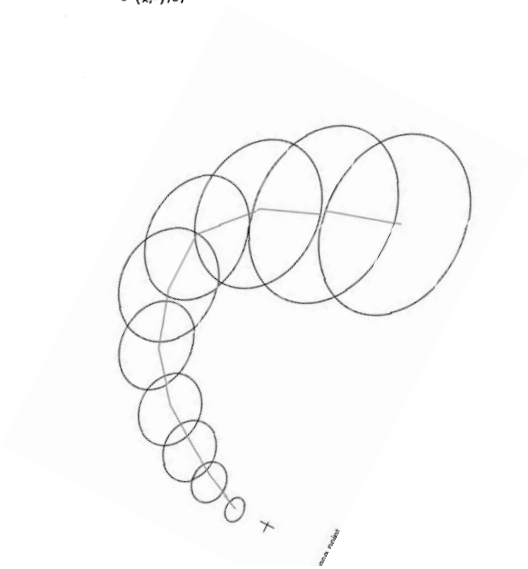
- Large industrial fires
- Major chemical spills
- Explosions
- *Weapons of Mass Destruction*
  - *Chemical*
  - *Biological*
  - *Radiological*

The Choice of Dispersion Model Depends on the Complexity and Type of Incident

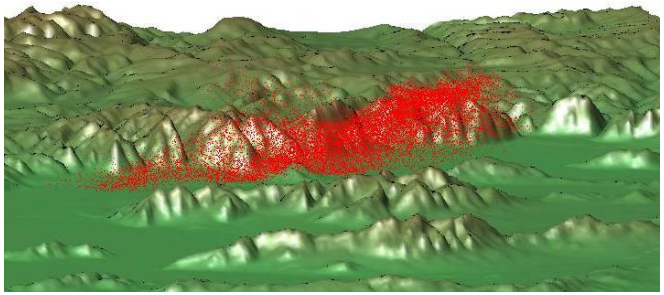
- Gaussian Plume



- Gaussian Puff



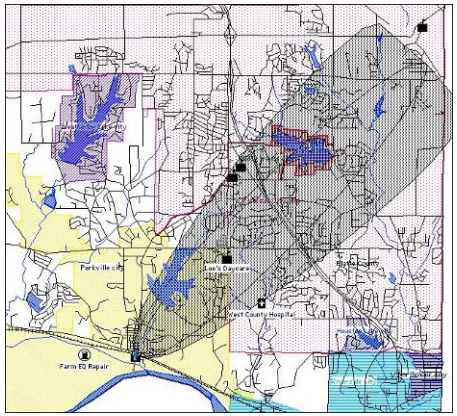
- Lagrangian Particle



Dispersion Models – Gaussian Plume

Characteristics:

- Fast-running
- Analytic & empirical
- Single meteorology input
- Steady-state and spatially uniform meteorology
- Simple source geometry
- Provide near-source magnitude of hazard area
- Downwind distance to 10 km



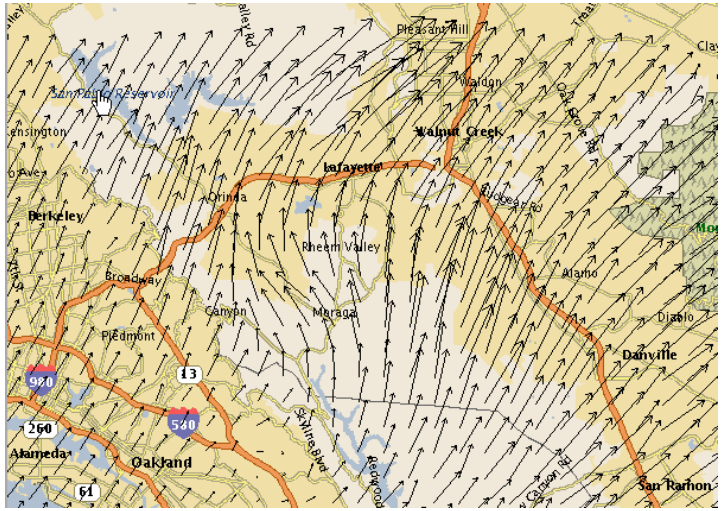
Applications:

- Planning calculations
- Real-time response

Runs on stand-alone PC

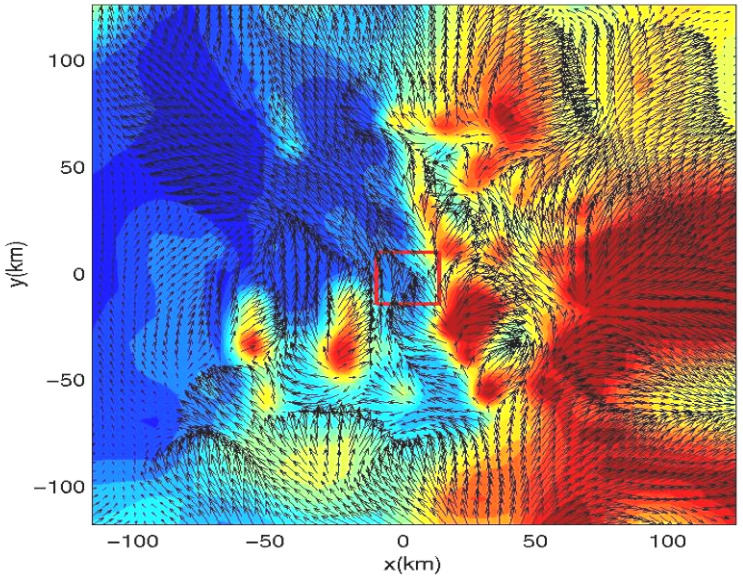
Time- and Space-Varying Meteorological Models are Employed for More Complex Dispersion Modeling Systems

- **Diagnostic**



- **Local and regional flows from *observed* meteorological data**
- **Adjustment for conservation of mass**
- **Empirical adjustments for terrain and thermal-stratification**
- **Idealized similarity-theory parameterization**

- **Prognostic**



- ***Forecast* boundary-layer and mesoscale flows (fronts, precipitation, land-sea breeze, mountain effects)**
- **Assimilate observations**
- **Solve conservation equations for thermodynamic energy, momentum and mass**

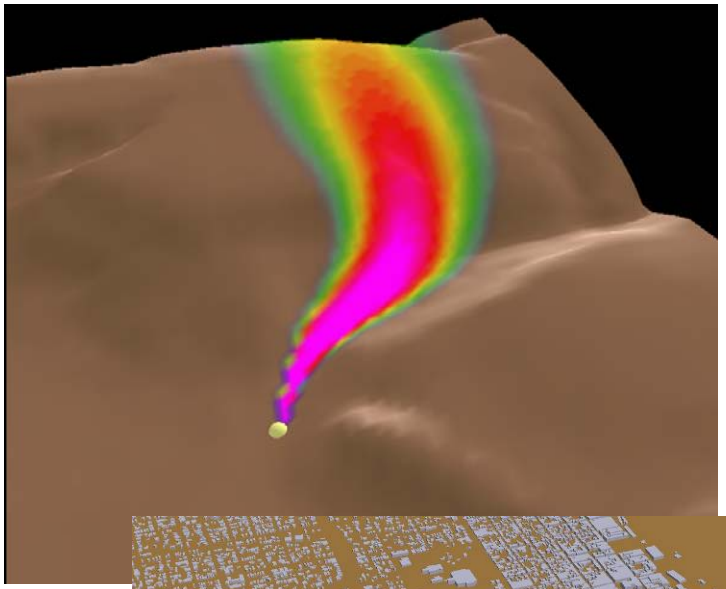
Expertise on local conditions resides with the National Weather Service forecast office

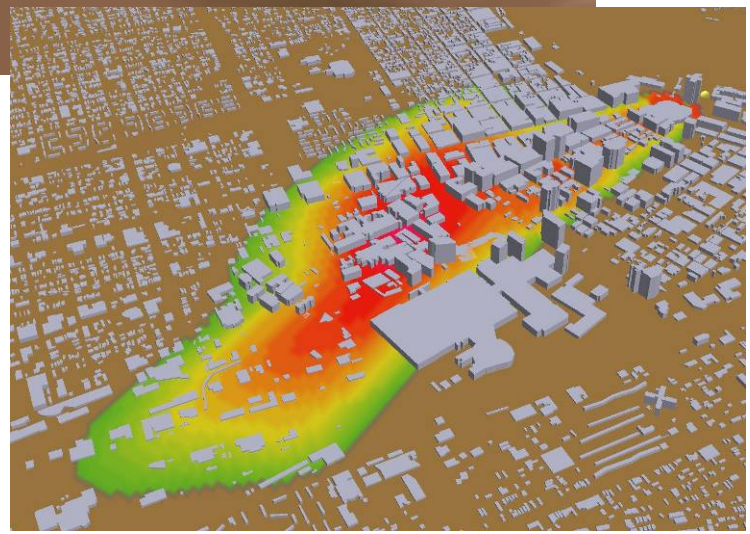
Dispersion Models – Gaussian Puff

Capabilities:

- Represent plume as superposition of multiple Gaussian spatial distributions for contaminant mass
- Time- and space-varying dispersion if coupled to appropriate meteorological data
- Empirical representation of physics such as denser-than-air or urban effects

- Applications:
  - Real-time response
  - Post-event assessment

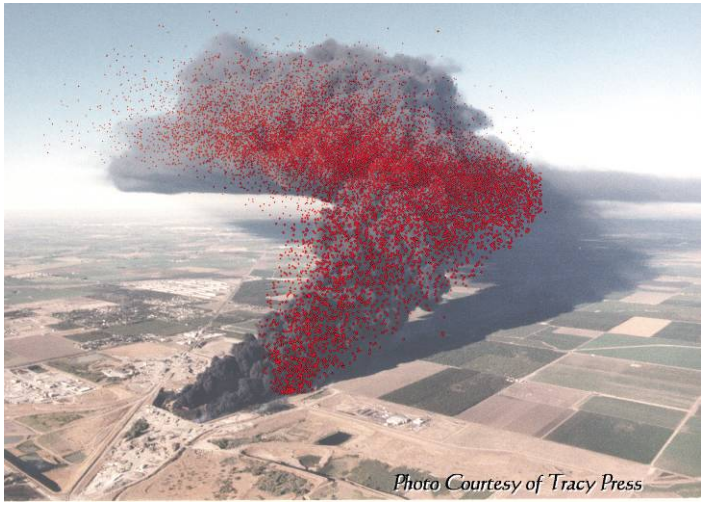




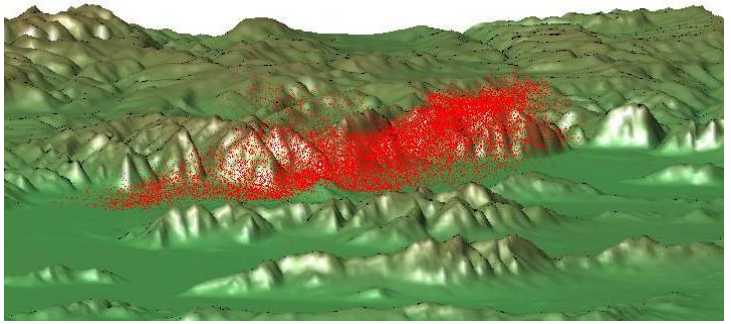
Runs on a stand-alone PC with real-time meteorological feed

Dispersion Models – Lagrangian Particle

- Capabilities:
  - Simulation of fluid particles marked with contaminant mass
  - Fully 3-D
  - Time- and space-varying
  - Inhomogeneous flows driven by regional- or building-scale models
  - Monte Carlo stochastic dispersion

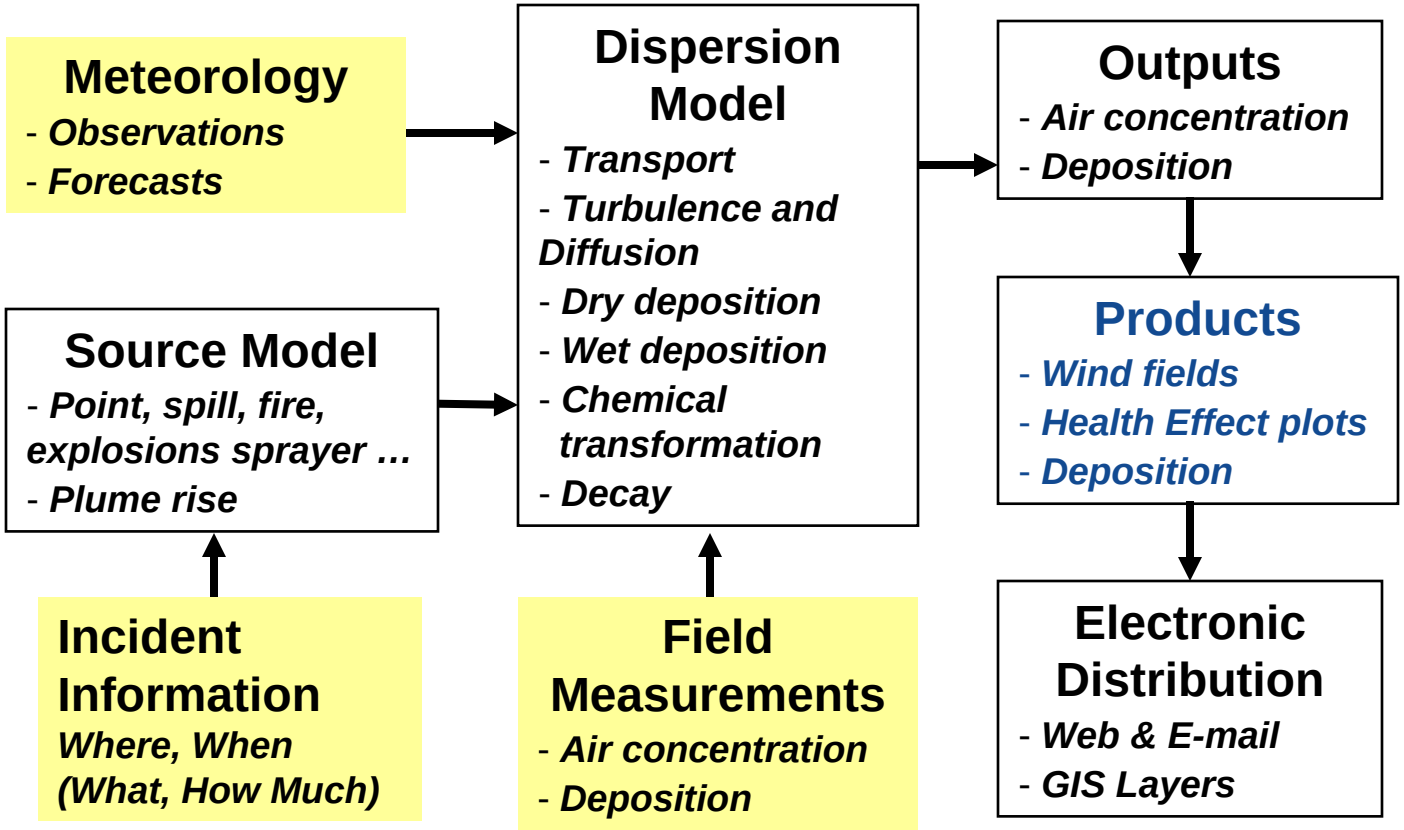


- Applications:
  - Real-time response
  - Post-event assessment



Runs on centralized reach-back system

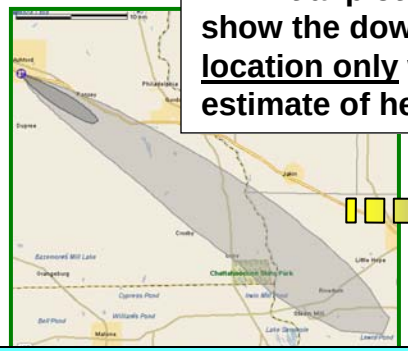
An Atmospheric Dispersion Modeling System Turns a Dispersion Model into a Useful Emergency Response Tool



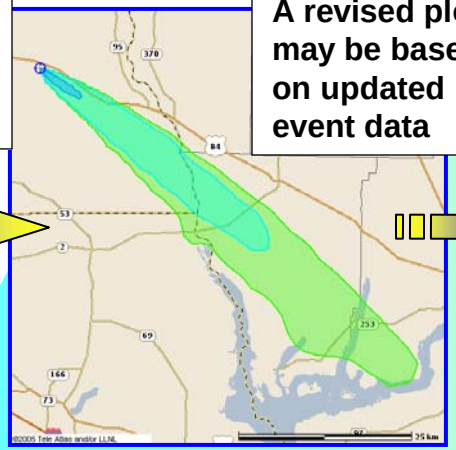
Supporting Databases

- Default source terms
- Material properties
- Terrain
- Land Use
- Population
- GIS maps
- Health effects criteria

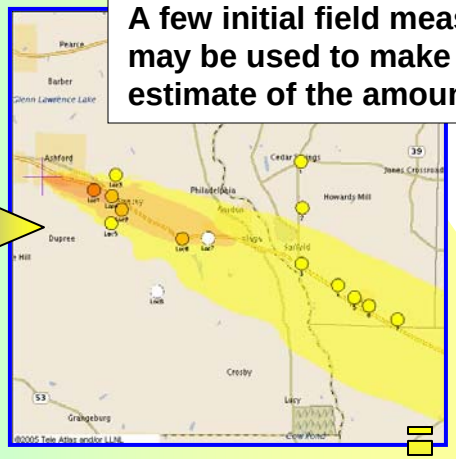
Modeling Systems Need Fast Methods of Receiving and Incorporating Field Monitoring Data to Update Plume Predictions



An initial plot may only show the downwind location only with no estimate of health effects



A revised plot may be based on updated event data

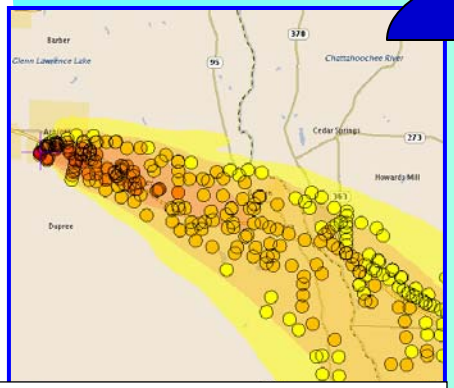


A few initial field measurements may be used to make an initial estimate of the amount released

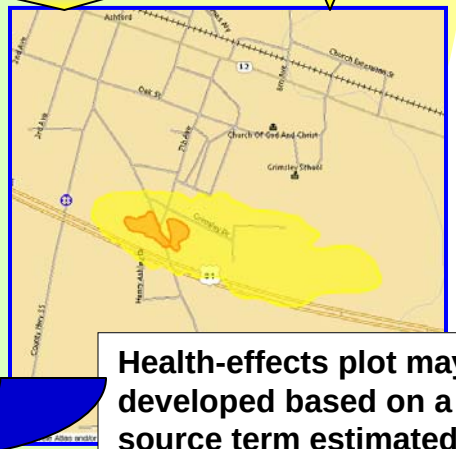
When little field data are available, models take a lead role

Example revised data: Updated source location, detailed weather

Source scaled to initial set of measurements



Cycle of new products based on updated sets of measure-ments



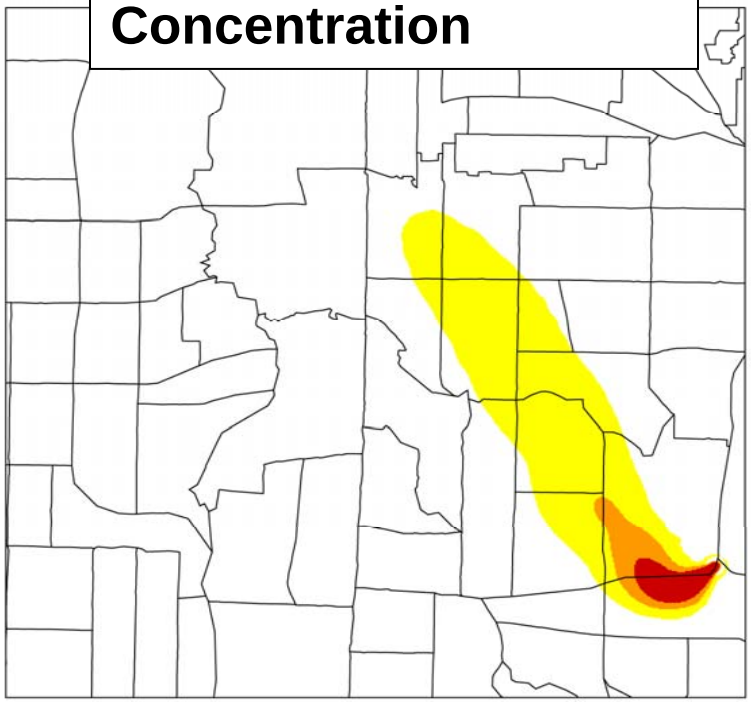
If extensive field data become available, that data can be used to describe effects

More extensive sets of field measurements will improve the accuracy of the source term and health effects calculations

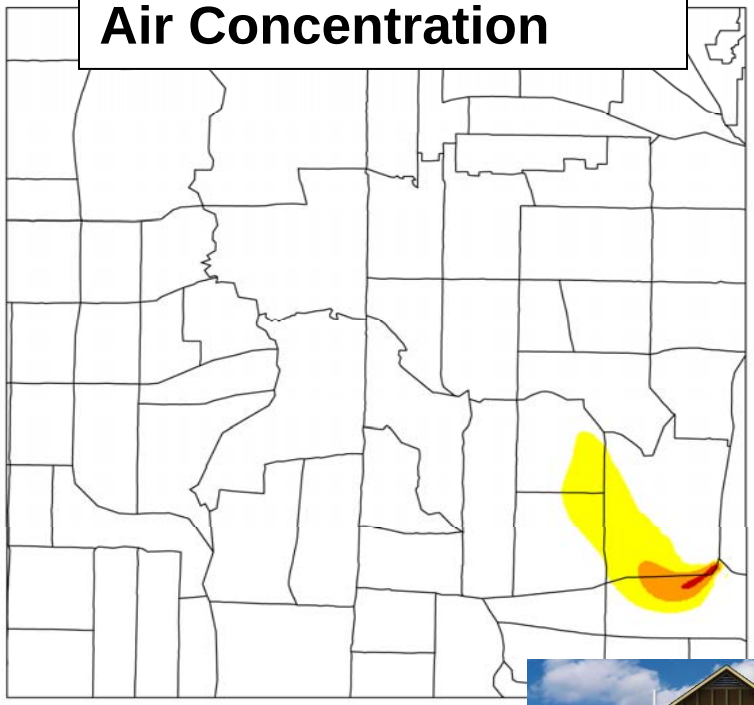
Health-effects plot may be developed based on a source term estimated from field measurements

Indoor Air Concentrations can be Substantially Less than Outdoors

Outdoor Plume Air Concentration

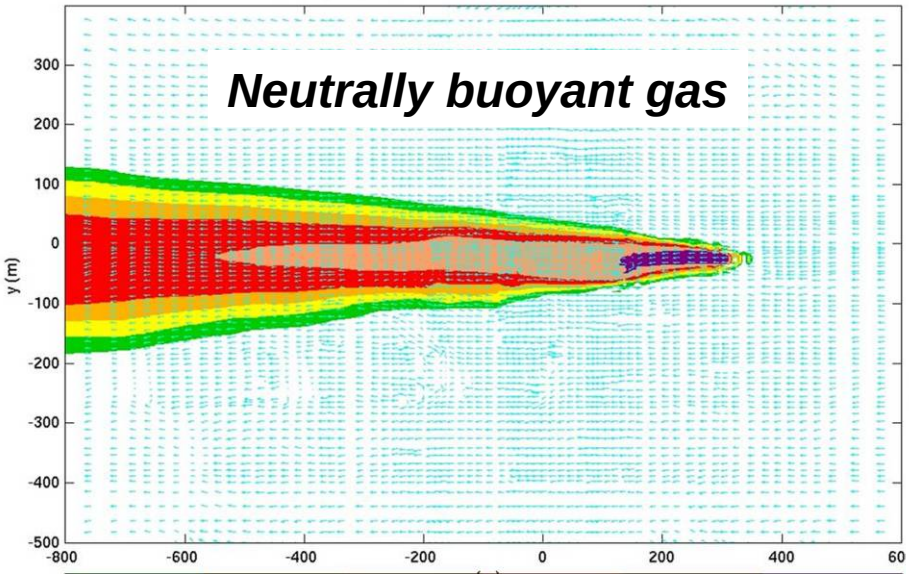


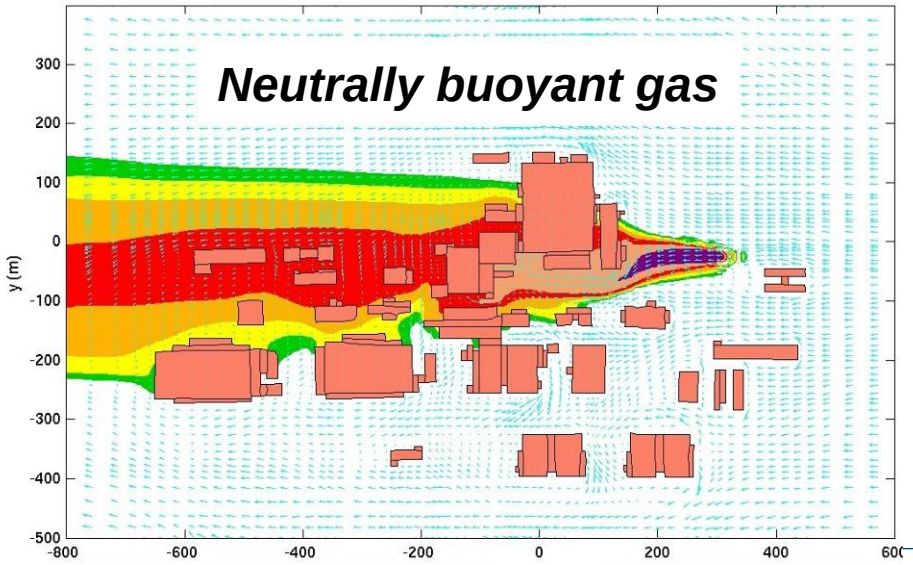
Corresponding Indoor Air Concentration

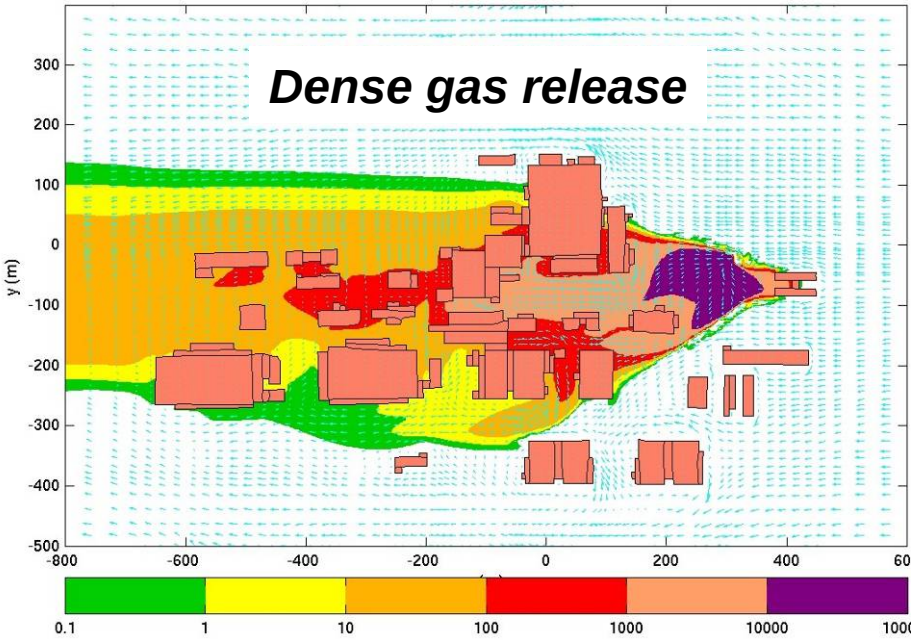


Building leakiness data may be used with Census data on residences for estimating indoor air concentrations

Building Effects and Dense Gas Releases Dramatically Change Dispersion Patterns







Density and buildings increase vertical mixing**,** lateral spreading near the source, and upwind dispersion, while potentially reducing downwind concentrations

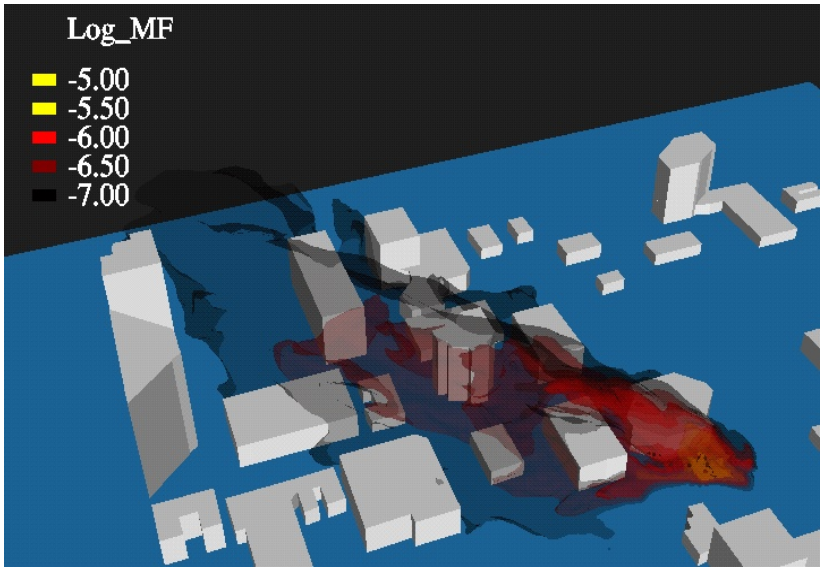
Specialized Computational Fluid Dynamics (CFD) Models Treat High-Resolution Building Flows

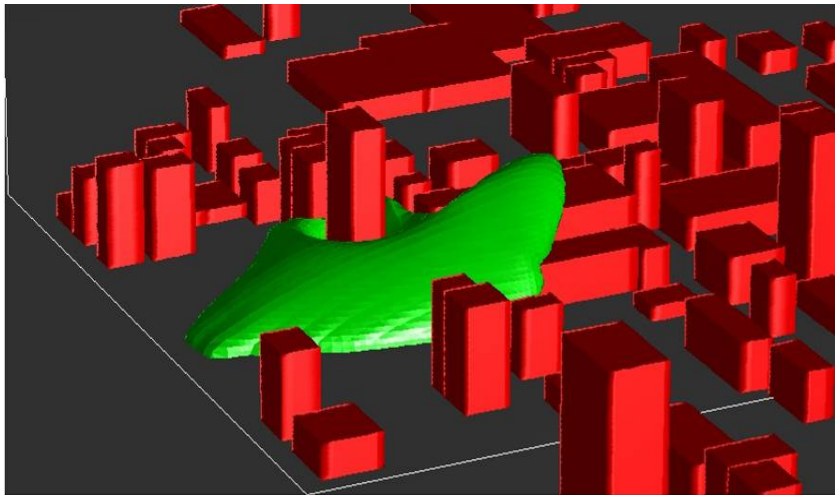
Capabilities:

- Spatially and temporally resolved flows around individual buildings and building groups
- Concentration fluctuations and peak concentrations

Applications:

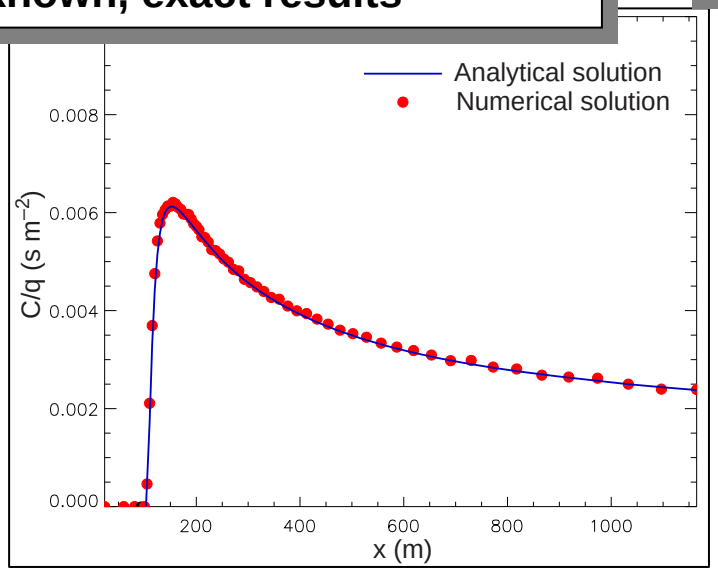
- Pre-event planning
- Pre-computed libraries of scenarios
- Post-event assessment



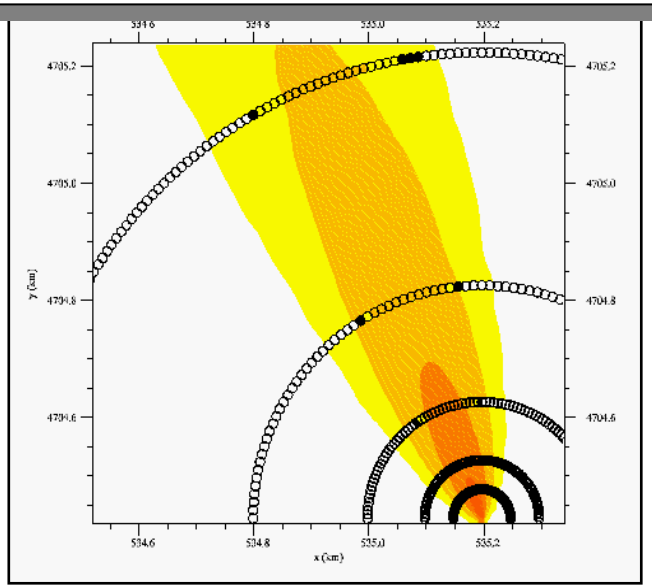


Model Systems Need to be Thoroughly Tested and Evaluated

- **Analytic solutions** test model components versus known, exact results



- **Field and laboratory experiments** test models in controlled, real-world conditions



- **Operational applications** evaluate the usability, efficiency, consistency and robustness of models for operational conditions

Different Responders use Modeling Products to Assist in Making Different Emergency Response Decisions

First responders

- Determine safe approach to the incident
- Locate the incident command site
- Select personal protective equipment
- Take initial field measurements
- Control access to incident

Specialized response and support teams

- Guide field measurement and sampling teams
- Determine evacuation routes
- Estimate number of casualties or illnesses to expect for hospitals

Emergency Managers and Public Affairs Officers

- Guidance for making shelter or evacuation recommendations
- Means to communicate decisions to the public (and allay concerns)





Technical Products Need to be Based on Standard Health Effect Criteria

Example for chemical releases:

Red: life threatening effects

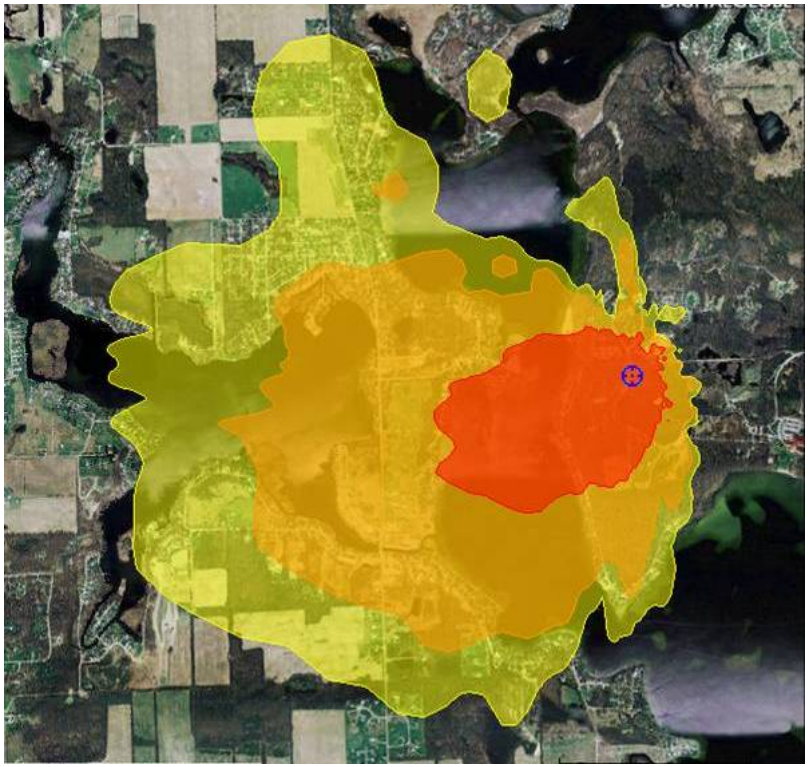
(AEGL3, ERPG3 or TEEL3)

Orange: serious long-lasting effects

(AEGL2, ERPG2 or TEEL2)

Yellow: notable discomfort

(AEGL1, ERPG1 or TEEL1)

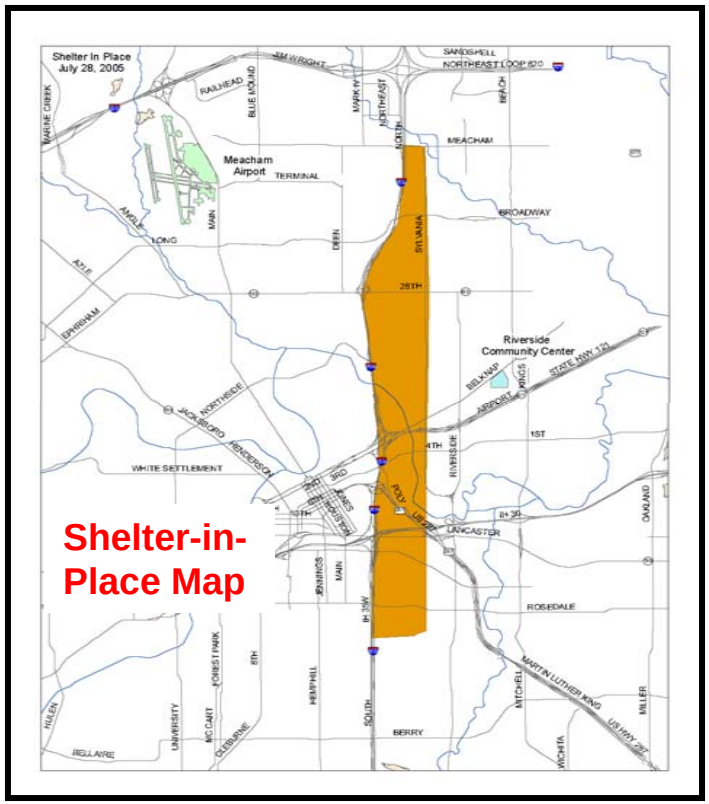


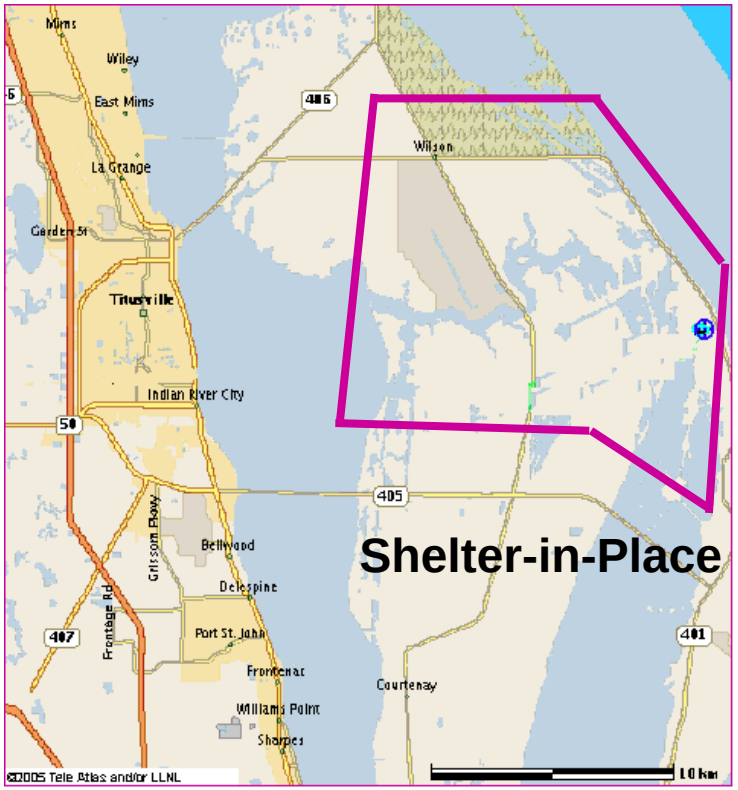
AEGL: EPA Acute Emergency Guideline Level
ERPG: American Industrial Hygiene Association (AIHA) Emergency Response Planning Guideline
TEEL: DOE Subcommittee on Consequence Assessment & Protective Actions (SCAPA) Temporary Emergency Exposure Limits

Reports need to include model inputs, assumptions, and uncertainty

Public Releasable "Briefing" Products Need to Show Protective Action Recommendations in a Simple and Straightforward Manner

Example Shelter-in-Place Maps based on Dispersion Model Calculations





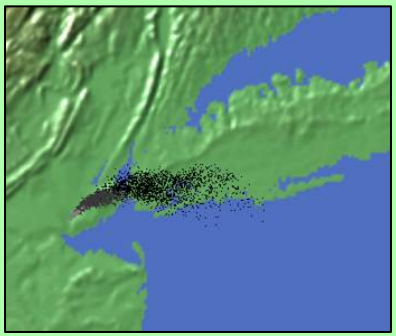
Summary: For Major Releases, Dispersion Modeling Systems Transform Incident Information into Actionable Information

Incident Information

- Meteorological data
- Source information (release time, location, height, material …)
- Measurement data and observations

Dispersion Modeling System

- Release mechanism models (spills, fires, explosions …)
- Meteorological model (steady-state, 3-D wind field, forecast)
- Transport and dispersion model



Actionable Information

- Hazard areas
- Health effect levels based on public exposure guidance
- Exposed populations (casualty and fatality estimates)
- Protective action guidance
- Planning and consequence assessments